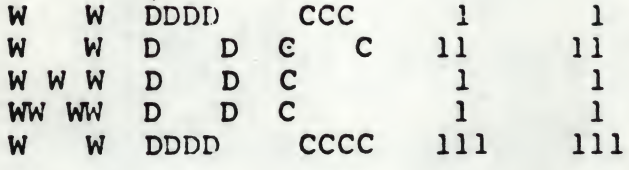
WDC11 Winchester Disk Controller

User's Manual

February 1982



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Notice To WDC11-C Users

The DL.SYS handler that is distributed with RT-11 is sysgenned to support only two RL01/2 units (DL0: & DL1:). If you wish to access more than two RL01/2 units, you must rebuild the DL.SYS handler with this support. An attempt to access DL2: or DL3: with the distributed DL.SYS handler will result in a "?DIR-F-Error reading directory" message, or something similar.

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- Commercial Message -

The text portion of this manual was prepared on an Andromeda 11/B computer system using VEDIT, the Video Editor. Camera-ready masters were printed with a daisy wheel printer using DPS V2, the enhanced Document Processing System, to format the output. VEDIT and DPS are software products available from Andromeda.

WDC11 User's Manual

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Appendices

1 Scope

The WDC11 User's Manual covers the Andromeda WDC11-B and WDC11-C Winchester Disk Controllers. The WDC11-B supports emulation of DEC RK05 and RX02 devices. The WDC11-C supports emulation of DEC RL01/2 and RX02 devices. This User's Manual is intended to provide enough information for a user to do the following:

1) Set up the WDC11 card for a specific system

2) Install the WDC11 card in a Q-Bus backplane

3) Connect the WDC11 to one or more supported disk drives

4) Format fixed and removable media as required

5) Use the WDC11 and connected drives as a mass storage subsystem with standard handler software

This manual does not contain enough information for a user to write his/her own software drivers to control the WDC11. For this information, the user is referred to the DEC manuals that contain detailed specifications of the emulated controllers.

Related documents:

DEC Microcomputer Interfaces Handbook

DEC RKV11-D User's Manual (EK-RKV11-OP)

DEC RLV12 Disk Controller User's Guide (EK-RLV12-UG-001)

DEC RX02 Floppy Disk System User's Manual (EK-ORX02-UG)

2 Introduction

This section of the manual contains a brief description of the WDC11, a list of its significant specifications, and a discussion of operational restrictions.

2.1 Description

The Andromeda Systems WDC11 Winchester Disk Controller is a single dual-width card which plugs directly into an LSI-11 computer system. To the system, the WDC11 may appear to be three separate peripherals- an RK05 or RL01/2 hard disk controller, an RX02 floppy disk controller, and a bootstrap ROM card.

* RK05 hard disk controller (WDC11-B)

The RK05 hard disk controller section is used to interface 8" or 5.25" Winchester disk drives to the LSI-11 bus. It is software compatible with DEC operating systems using the RK or DK handlers. Each Winchester disk drive may contain from 1 to 8 logical RK units, depending on the amount of data storage available. Eight logical units are accessible for a total data storage capacity of 19.2 Mbytes. Formatting of individual RK/DK units is supported. The WDC11-B includes 22-bit DMA addressing capability not found on the DEC RKV11-D disk controller.

* RL01/2 hard disk controller (WDC11-C)

The RL01/2 hard disk controller section is used to interface 8" or 5.25" Winchester disk drives to the LSI-11 bus. It is software compatible with DEC operating systems using the DL handler. Each Winchester disk drive may contain from 1 to 4 logical DL units, depending on the amount of data storage available. Each logical unit may be either an RL01 or an RL02, and different types of units may be mixed on the same physical drive. Four logical units are accessible for a total data storage capacity of 41.92 Mbytes. Formatting of individual DL units is supported. The WDC11-C emulates the DEC RLV12 disk controller, including 22-bit DMA addressing capability.

* RX02 floppy disk controller

The RX02 controller section is used to interface 8" or 5.25" floppy disk drives to the LSI-11 bus. It is software compatible with DEC operating systems using the DY handler. In addition, 8" diskettes are media compatible with DEC RX01/RX02 single and double density diskettes, and with Andromeda FDC11/DFDC11 single density diskettes. Double headed disk drives are supported, and two logical units are accessible, for a total data storage capacity of over 2 Mbytes. True

formatting (of both headers and data) is supported in both single and double density.

* Bootstrap ROM

The bootstrap ROM section will automatically bootstrap RK0:/DK0: (WDC11-B), DL0: (WDC11-C), or DY0: upon power up or system reset. Any RK/DK, DL, or DY unit may be manually bootstrapped by entering the device specification at the console terminal.

All data transfers to and from both Winchester and floppy disks are via Direct Memory Access. Twenty-two bits of memory address are implemented in the Winchester section allowing direct access to over 4 Mbytes of processor memory.

Communication to all disk drives is via a single 50 line cable for easy system integration. This cable will interface directly with a single 5.25" Winchester drive. Multiple 5.25" Winchester drives, 8" Winchester drives, and any floppy drives must connect to this cable via personality cards. The WDC11 may control any combination of similar Winchester drives and similar floppy drives (four drives total), and all drives may be individually write protected via external switches.

The WDC11 may be connected to the following types of drives:

5.25" Winchester with Seagate Technology ST506 type interfaces, WPC5W personality card required for multiple drives

8" Winchester with Shugart Associates SA1000 type interfaces, WPC8W personality card required

5.25", double headed, 96 TPI floppy with Tandon Magnetics TM100-4 type interfaces, WPC5F personality card required

8" floppy with Shugart Associates SA800/850 type interfaces, WPC8F personality card required

Future disk controller products in the WDC11 family will emulate the RP02 hard disk controller (WDC11-D), to provide total data storage capacities from 2.5 Mbytes to 160 Mbytes.

2.2 Specifications

Size:	1 Dual-Width Card; 5.187" x 8.94" x 0.5"
Power consumption:	+5V DC @ 3.0A
Q-Bus loading:	2 AC loads 1.5 DC loads

Addressing:	16, 18, and 22 bit DMA capability
Data Transfer Rates:	187 Kbytes/second, 5.25" Winchester, single cylinder, 3:1 interleave
	140 Kbytes/second, 5.25" Winchester, multi-cylinder, 3:1 interleave
	163 Kbytes/second, 8" Winchester, single cylinder, 3:1 interleave
	122 Kbytes/second, 8" Winchester, multi-cylinder, 3:1 interleave
	8.32 Kbytes/second, 5" Floppy, single cylinder
	9.98 Kbytes/second, 8" Floppy, single cylinder, double density (RX02)

2.3 Restrictions

While the WDC11 will emulate up to three separate devices, it is not three separate devices. Rather, it has a high speed processor and a general purpose organization that allows it to appear to be all of these devices. However, there are restrictions on the use of the WDC11 that would not apply to the use of separate devices. Specifically it can emulate only one device at a time.

Under most operational conditions, only one of the WDC11 controllers (Winchester or floppy) would be in use at a time. Since the majority of the logic of the WDC11 is shared between the disk controllers (and to a lesser extent, the Bootstrap ROM) it cannot support concurrent operations among its devices.

Examples of the operational restrictions of the WDC11 are as follows:

1) The bootstrap code copies itself into system RAM memory (Locations 1000-1776) and executes from there so that when the disk is accessed during the bootstrapping operation, the WDC11 will not be trying to emulate a ROM and a disk controller at the same time.

2) In a copy operation from Winchester to floppy (or vice-versa), the following sequence of operations is supported by the WDC11: a) Transfer data from Winchester to system memory, b) Transfer data from system memory to floppy, c) repeat. Not supported, are concurrent I/O transfers involving the Winchester and floppy sections of the WDC11: a) Transfer data from Winchester to system memory area labeled "ABC", b)

Start transfer from system memory area labelled "ABC" to floppy, c) Before step "b" is complete, begin a new transfer from Winchester to system memory area labelled "DEF".

3) Also not supported by the WDC11 are unrelated concurrent I/O transfers such as those that might occur in a multi-user or multi-task system.

If the WDC11 on-board processor is busy emulating one device, typically doing a DMA transfer, it will not accept a command (write operation) for any of the other devices. An attempt by the LSI-11 CPU to read a WDC11 register while the WDC11 is busy will result in all-zeros being returned. An attempt to write into a WDC11 register under these conditions would result in a bus timeout error (the WDC11 would not assert REPLY).

A software solution to this restriction is simple. The handlers that control the WDC11 should test the controller Command Status Register for a READY status before loading a new command. If the WDC11 is busy, the all-zero data returned in response to a read would indicate a BUSY condition. Unfortunately, most standard handler software assumes that if it left its controller in a READY state, that it will remain in a READY state. Thus, these handlers do not usually test the controller READY status again before loading a new command. Another solution is for the operating system to refrain from concurrent I/O (RT-11SJ works this way normally).

In conclusion, the operation of the bootstrap code should cause no problem unless the system memory does not contain RAM from locations 1000 to 1776. The concurrent I/O limitation will not cause problems unless concurrent I/O is attempted. If you plan to run a system that will attempt concurrent I/O, you should probably not use the floppy section of the WDC11. These restrictions are due to the sharing of logic on the WDC11 card that enabled all of the functions to fit on a dual-width card.

3 Installation

Installation of the WDC11 in your system consists of the following steps: 1) Confirm that the PROM configuration of the card is correct. 2) Set up any required jumper options. 3) Plug the WDC11 card into an appropriate slot in the Q-Bus backplane. 4) Connect the WDC11 card to the disk drive (or drives). Each of these steps is discussed in this section.

For a map of the physical locations of the PROMs and jumpers discussed in this section, see the WDC11 Physical Board Layout diagram in Appendix C.

3.1 PROM Configuration

The functional characteristics of the WDC11 are determined to a large extent by the configuration PROM chips that are plugged into the card. The configuration that you require should have been specified at the time that you ordered the WDC11. The PROMs that are were installed in the WDC11 at the time of shipment were based on that specification. At this time you should confirm that the WDC11 has the proper configuration PROMs for you.

To check the configuration PROMs in your WDC11, see appendix B of this manual, which lists the PROMs installed by Andromeda. (If you received your WDC11 from a source other than Andromeda, the WDC11 may have been reconfigured. If so, your dealer may supply you with a separate configuration sheet.) In addition to this manual, you will need the Andromeda document, "WDC11 Configuration PROMS", which lists the labels and functions of all of the currently defined configuration PROMs for the WDC11.

To confirm that your WDC11 has the appropriate set of configuration PROMs, compare the PROMs listed on the configuration sheet with those defined in the "WDC11 Configuration PROMS" list. For example: If you ordered a WDC11 that was to emulate 3 RL02 drives on a Quantum Q2040 8" Winchester disk drive and an RX02 drive on an SA800 8" floppy disk drive and did not request non-standard Q-Bus addresses and vectors, your configuration sheet should show the following:

PROMS:	Function	Installed Type
	Bootstrap ROM	WBRCCx
	Address Recognition	WADCA
	Microcode	WDCCxx

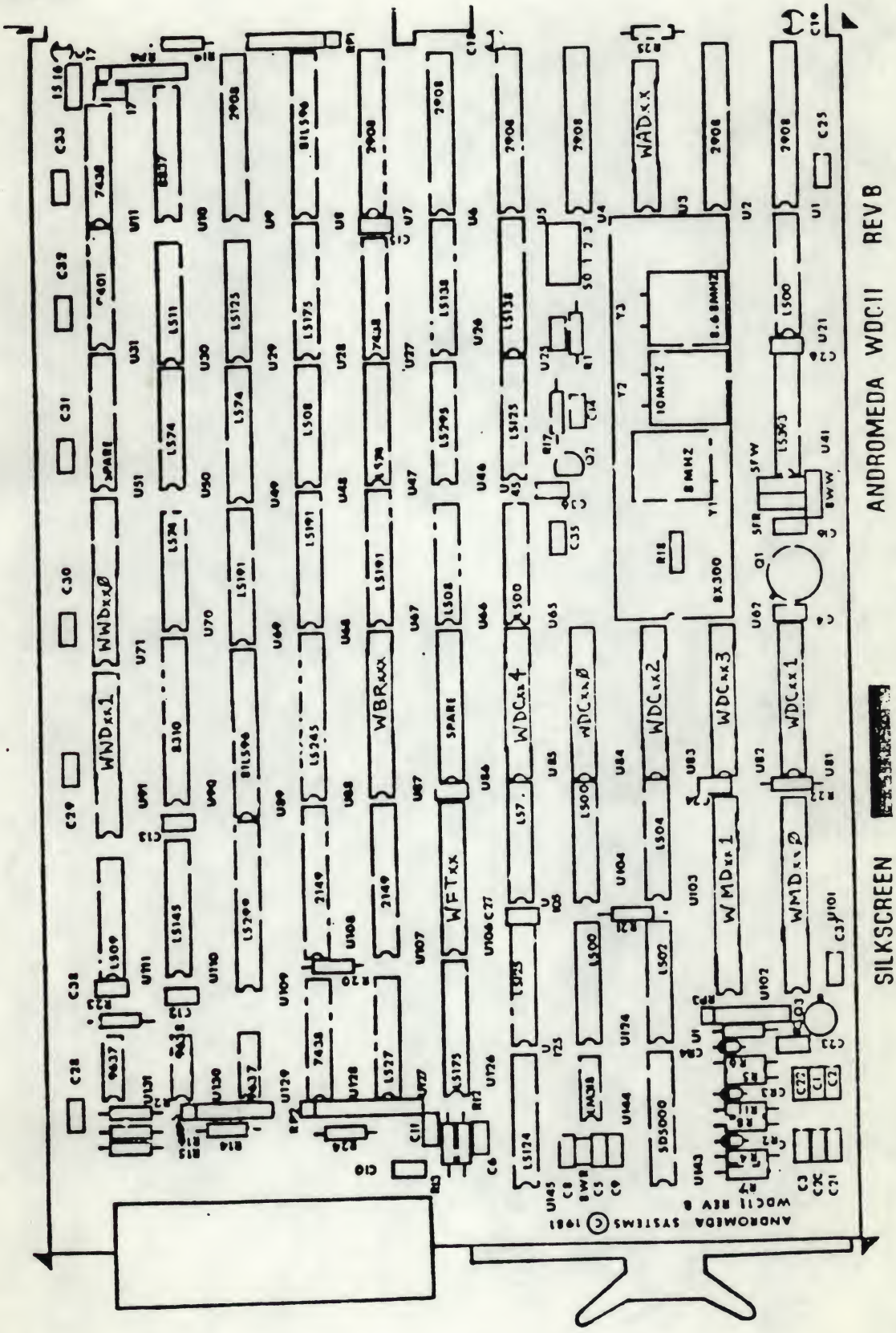
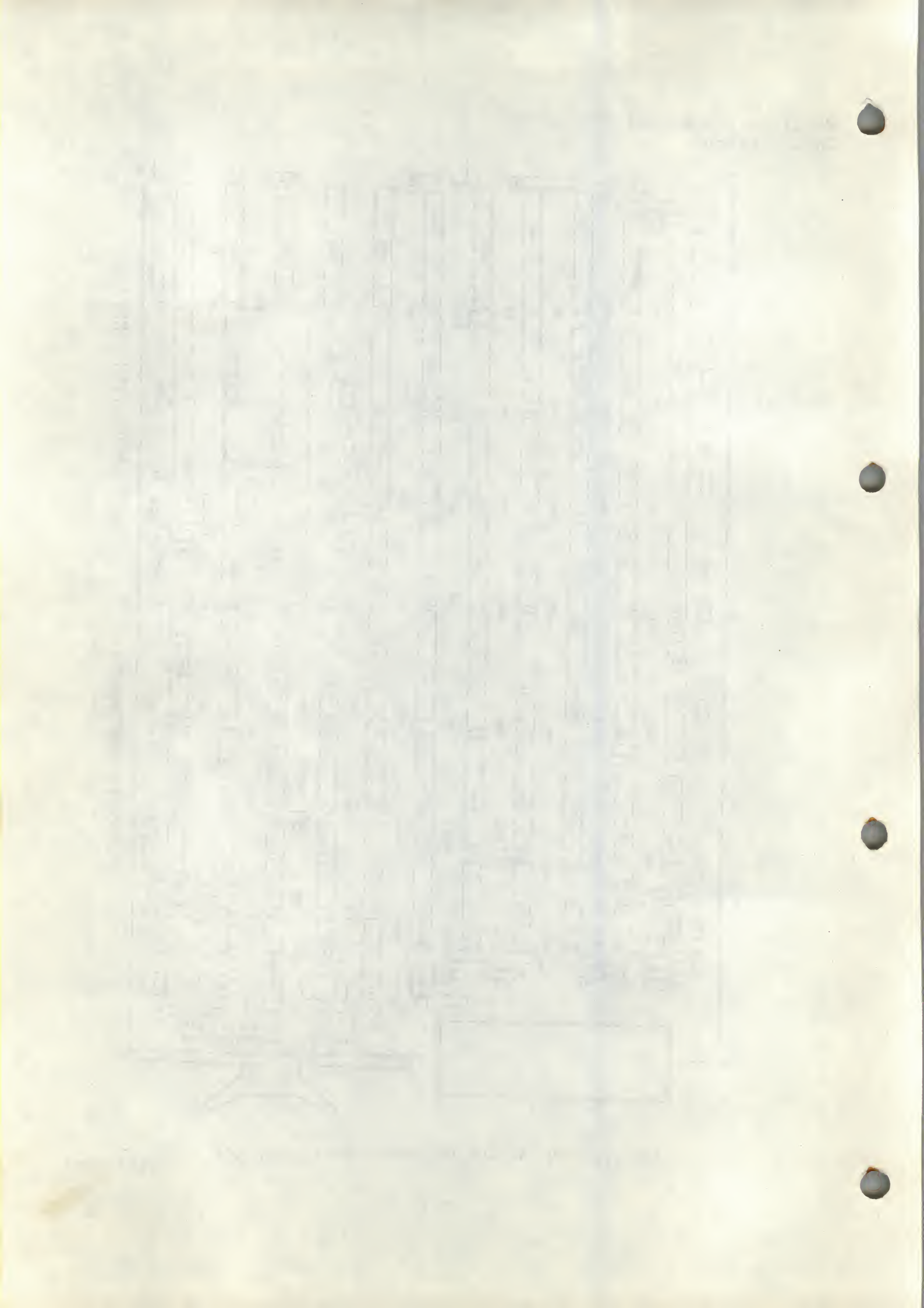


Figure 3.0 WDC11 Physical Board Layout



For the configuration in the example, an 8" Winchester and an 8" floppy drive, the configuration sheet should also show the following jumpers installed: 8WR, 8WW, 8FR, and 8FW (these jumpers are described below).

You should contact Andromeda or your dealer if the PROM configuration in your WDC11 does not correspond with your requirements. (The other PROMs listed on the configuration sheet do not affect the functionality of the WDC11).

3.2 Jumper Options

If the PROMs and drive type jumpers are correct for your system, the next step is to check the other jumper options on the WDC11 card and change them if necessary. These other jumper options control the Q-Bus addresses that the WDC11 will respond to: The Peripheral Selection jumpers; and the hardware interrupt priority of the WDC11: The Interrupt Priority jumpers.

3.2.1 Peripheral Selection

There are four jumpers on the WDC11 board near U25 labelled 'S3', 'S2', 'S1', and 'S0', which determine which peripherals the WDC11 will appear to be as follows:

S3 — An RK05 controller with registers addressed from 777400 thru 777416, and an interrupt vector of 220 (WDC11-B), or

an RL01/2 controller with registers addressed from 774400 thru 774416, and an interrupt vector of 160 (WDC11-C)

S2 — An RX02 controller with registers addressed from 777170 thru 777172, and an interrupt vector of 264

S1 — A bootstrap ROM, addressed from 773000 thru 773776

S0 — Four maintenance registers, addressed from 770500 thru 770506 (This jumper should NEVER be installed by the user. Writing into one of these registers may result in loss of disk data.)

Note: The above addresses assume that you are using a standard addresses. See section 3.1 for information on the Address PROM.

When a jumper is installed, the addresses for that particular peripheral will appear in the I/O page. A jumper is installed by a

jumper plug which connects two wire wrap pins together. The WDC11 is factory configured with jumpers S3, S2, and S1* installed. To disable a particular peripheral, remove the jumper plug.

For example, to disable the bootstrap ROM, remove jumper S1.

3.2.2 Interrupt Priority

Some LSI-11 processors have a four level interrupt priority scheme. The interrupt level of the WDC11 is configured via 3 jumpers near U11 labelled 'I5', 'I6', and 'I7'. The WDC11 is factory configured to interrupt at level 5, the normal level for disk devices, via a jumper etched on the rear of the board at I5.

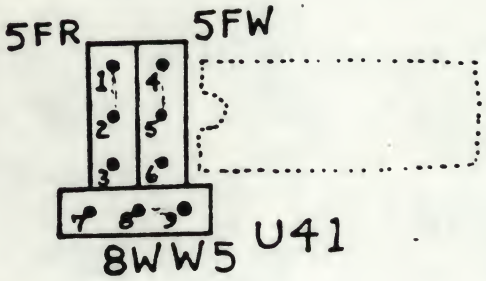
To change the interrupt priority, cut the jumper etched on the rear of the board at I5, and install jumpers as follows:

Level	Jumpers	
4	(none)	
5	I5	(factory configuration)
6	I6	
7	I6 & I7	

While the WDC11 is able to request an interrupt at any level, it will always respond to an interrupt acknowledge as if it were a level 7 device. Therefore, devices with a higher interrupt priority then the WDC11 should be installed electrically closer to the processor. See the DEC Microcomputers and Memories handbook for further details.

3.2.3 Physical Drive Configuration

The WDC11 is configurable for either 8" or 5.25" Winchester drives, and for either 8" or 5.25" floppy drives. (Note that the WBRxxx PROM must match the types of drives to be used.) This configuration involves four sets of jumper pads. These are labelled '8WR', '8WW/5WW', '8FR/5FR', and '8FW/5FW'. Jumper 8WR is located near U144. Jumpers 8WW/5WW, 8FR/5FR, and 8FW/5FW are located near U41.



Jumper Pair:	Pins	
5FR	1-2	x
8FR	2-3	
5FW	4-5	x
8FW	5-6	
5WW	8-9	x
8WW	7-8	

Figure 3.1 Physical Drive Configuration Jumpers Near U41

The configurations for Winchester and floppy drive sizes are:

Drive Type	Jumpers Installed
8" Winchester	8WR, 8WW
5.25" Winchester	5WW
8" Floppy	8FR, 8FW
5.25" Floppy	5FR, 5FW

Only the jumpers specified above are to be installed. The complementary jumpers must be removed. For example, if you are using an 8" floppy drive, install 8FR and 8FW and remove 5FR and 5FW. Note that all Winchester drives must be of the same size, and that all floppy drives must be of the same size, but that the Winchester and floppy sizes may be different from each other.

3.3 Q-Bus Installation

The WDC11 controller is installed by plugging it into a standard LSI-11 backplane. The hard disk section of the WDC11 supports, but does not require, a 22-Bit Q-Bus. Since the WDC11 is a device which can request interrupt service or DMA access to the bus, it must be installed so that the the interrupt acknowledge/DMA grant daisy chain is unbroken. Also, the WDC11 should be given a fairly high priority by installing it electrically near the LSI-11 processor. However, if there are DMA devices in your system without sector buffers (such as a magnetic tape controller or an Andromeda DFDC11 floppy controller) they should be at

a higher priority than the WDC11. See the DIGITAL Microcomputers and Memories handbook for further details.

3.4 Disk Drive Interface

When the WDC11 has been installed in the Q-Bus backplane, the next step is to connect it to one or more disk drives. This section discusses disk drive connection considerations.

The chip containing the bootstrap ROM code (U87) also contains information about what types of Winchester and floppy drives the WDC11 is controlling (e.g., drive capacity, step rate, etc.). This chip must remain installed even if the bootstrap ROM is disabled by removing jumper S1. To change the drive type (e.g., switch from an CMI5616 5.25" Winchester drive to an RMS512 5.25" Winchester drive), a different bootstrap ROM must be installed. Always turn off the power when removing or installing chips, and make sure that the chip is correctly oriented.

A list of the currently defined Bootstrap ROM chips is contained in the Andromeda document, "WDC11 Configuration PROMS".

3.4.1 Cable Specifications

The WDC11 50 line I/O cable (J1) will interface directly with a single 5.25" Winchester drive. Other Winchester and floppy drives must connect to this cable via personality cards. The following section describes how to connect the 50 line I/O cable to the 34 line and 20 line card edge connectors on a single 5.25" Winchester drive. Pin 1 of J1 is the upper pin on the end of the connector near the center of the card.

The pinout of J1 is as follows:

Ground	Signal	Description	5.25" Winchester Drive Connection
1	2	Write Current	J1-1,2
3	4	Head Select 2	J1-3,4
5	6	Write Gate	J1-5,6
7	8	Seek Complete	J1-7,8
9	10	Track 0	J1-9,10
11	12	Write Protect	J1-11,12
13	14	Head Select 0	J1-13,14
15	16	(spare)	J1-15,16
17	18	Head Select 1	J1-17,18
19	20	Index	J1-19,20
21	22	Ready	J1-21,22
23	24	Step	J1-23,24
25	26	Drive Select 0	J1-25,26
27	28	Drive Select 1	J1-27,28
29	30	Drive Select 2	J1-29,30
31	32	Drive Select 3	J1-31,32
33	34	Direction	J1-33,34
35	36	F Head Load	(Floppy only, do not connect to
37	38	F Write Data	5.25" Winchester Drive)
39	40	F Read Data	
41,42		Ground	J2-11,12
	43	W Write Data +	J2-13
	44	W Write Data -	J2-14
45,46		Ground	J2-15,16
	47	W Read Data +	J2-17
	48	W Read Data -	J2-18
49,50		Ground	J2-19,20

Pins 35-40 must be left open. Do NOT connect them to 5.25" Winchester drive pins J2-5 thru J2-10. Note that Winchester drive pins J2-1 thru J2-10 are unused.

4

gilt nur für einzelne Winchester ohne Floppy

3.4.2 Personality Cards

For systems containing anything other than a single 5.25" Winchester drive, personality cards are needed to adapt the WDC11 50 line I/O cable to each particular drive.

Current personality cards include:

* 2X WPC5W Personality card for 5.25" Winchester drives if more than one Winchester drive is used
* WPC8W Personality card for 8" Winchester drives
* 1X WPC5F Personality card for 5.25" floppy drives
* WPC8F Personality card for 8" floppy drives

Personality cards perform one or more of the following functions:

Rearrange control signal lines (WPC8W, WPC8F, WPC5F)
Perform radial data multiplexing (WPC8W, WPC5W)
Translate radial data levels (WPC8W)
Provide auxiliary timing signals (WPC8W)

Each personality card plugs directly on to the back of its drive (without extending beyond the drive envelope), and contains a 50 line flat cable connector which interfaces directly with the WDC11 50 line I/O cable.

Examples:

1) System with one 5.25" Winchester drive and one 5.25" floppy drive. You will need a WPC5F for the floppy drive, but no personality card for the Winchester.

2) System with two 5.25" Winchester drives and two 5.25" floppy drives. You will need two WPC5W personality cards, one for each Winchester drive, and two WPC5F cards, one for each floppy drive.

3) System with one 5.25" Winchester drive and two 8" floppy drives. You will need two WPC8F cards, one for each floppy, but no personality card for the Winchester.

4) System with one 8" Winchester drive and one 8" floppy drive. You will need one WPC8W for the Winchester and one WPC8F for the floppy drive.

3.4.2.1 WPC5W

The WPC5W personality card is used to connect the WDC11 50-line disk drive cable to 5.25" Winchester disk drives in systems that contain more than one 5.25" Winchester drive.

The WPC5W contains four jumper pairs that you must configure. These jumpers are located next to IC U2, and are numbered 1 through 8. All of these jumpers enable the termination of a specific signal line when installed.

Jumper Pair	Line Terminated	Configuration
1-5	Winchester Read Data +	Install in last WPC5W only
2-6	Winchester Write Data +	Install in last WPC5W only
3-7	Floppy Write Data L	Leave open in all WPC5W
4-8	Floppy Head Load L	Leave open in all WPC5W

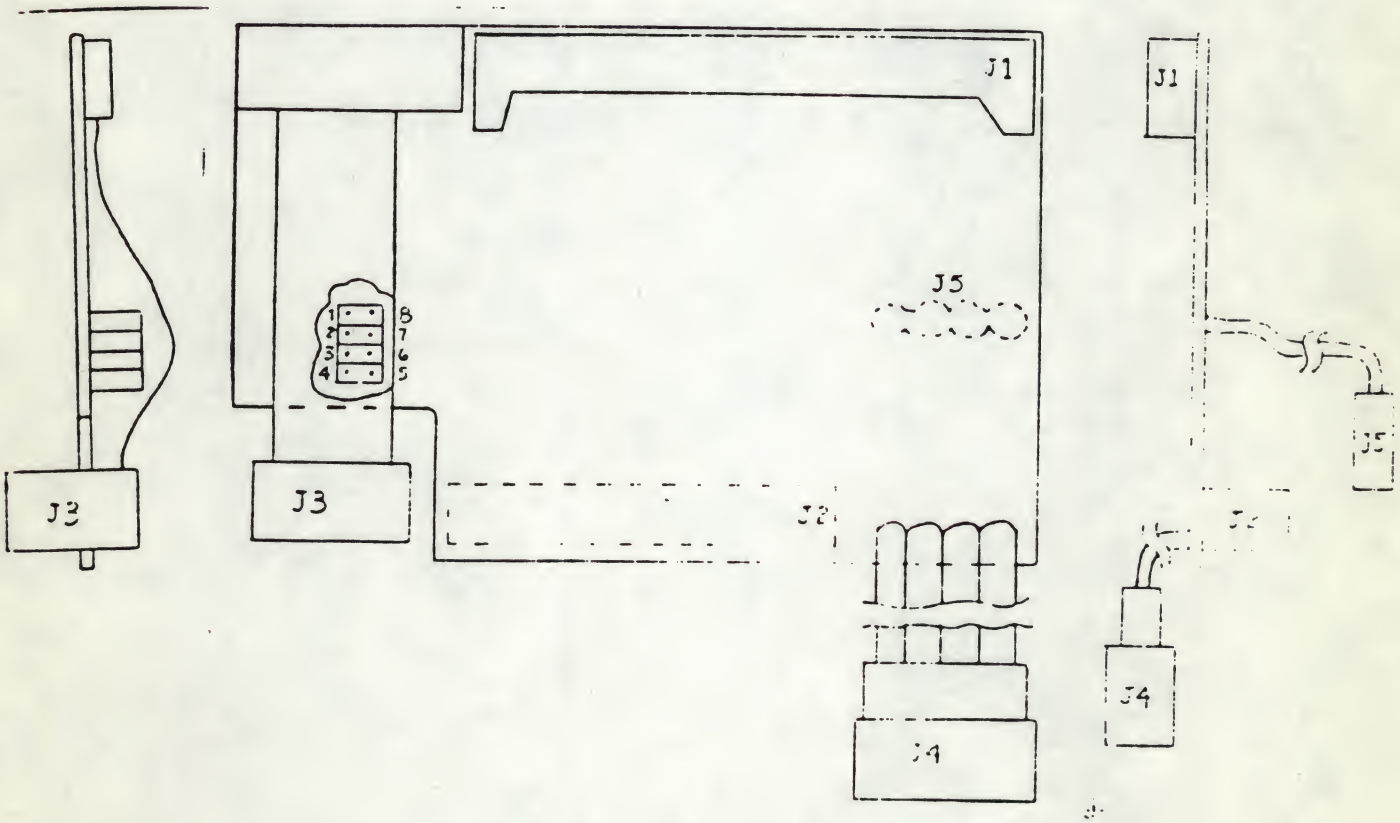


Figure 3.2 WPC5W Physical Board Layout

Once the WPC5W has been configured for the Winchester drive on which it will be installed, it may be attached to that disk drive. The WPC5W requires +5VDC power for its terminators and active components. The card gets its power from the cable that would normally plug directly into the 5.25" disk drive. Attach the WPC5W to the disk drive as shown in figure 3.3, below. Plug J2, the 34-line PC edge connector of the WPC5W on to J1, the 34-line connector of the disk drive. Plug the male power connector of the WPC5W into the female power connector of the disk drive. Plug the 20-line PC edge connector on to the J2 connector of the disk drive. When you install this assembly in your system, plug the 50-line cable from the WDC11 into the J1 connector of the WPC5W and plug the male power connector from your system's power supply into the female power connector of the WPC5W.

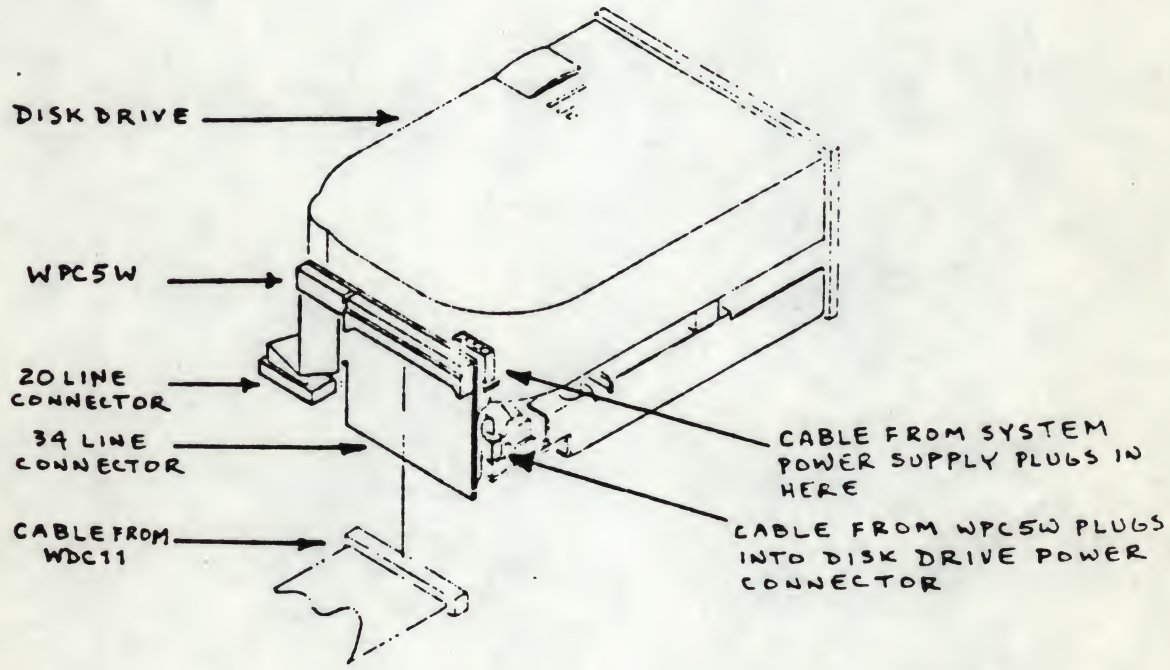
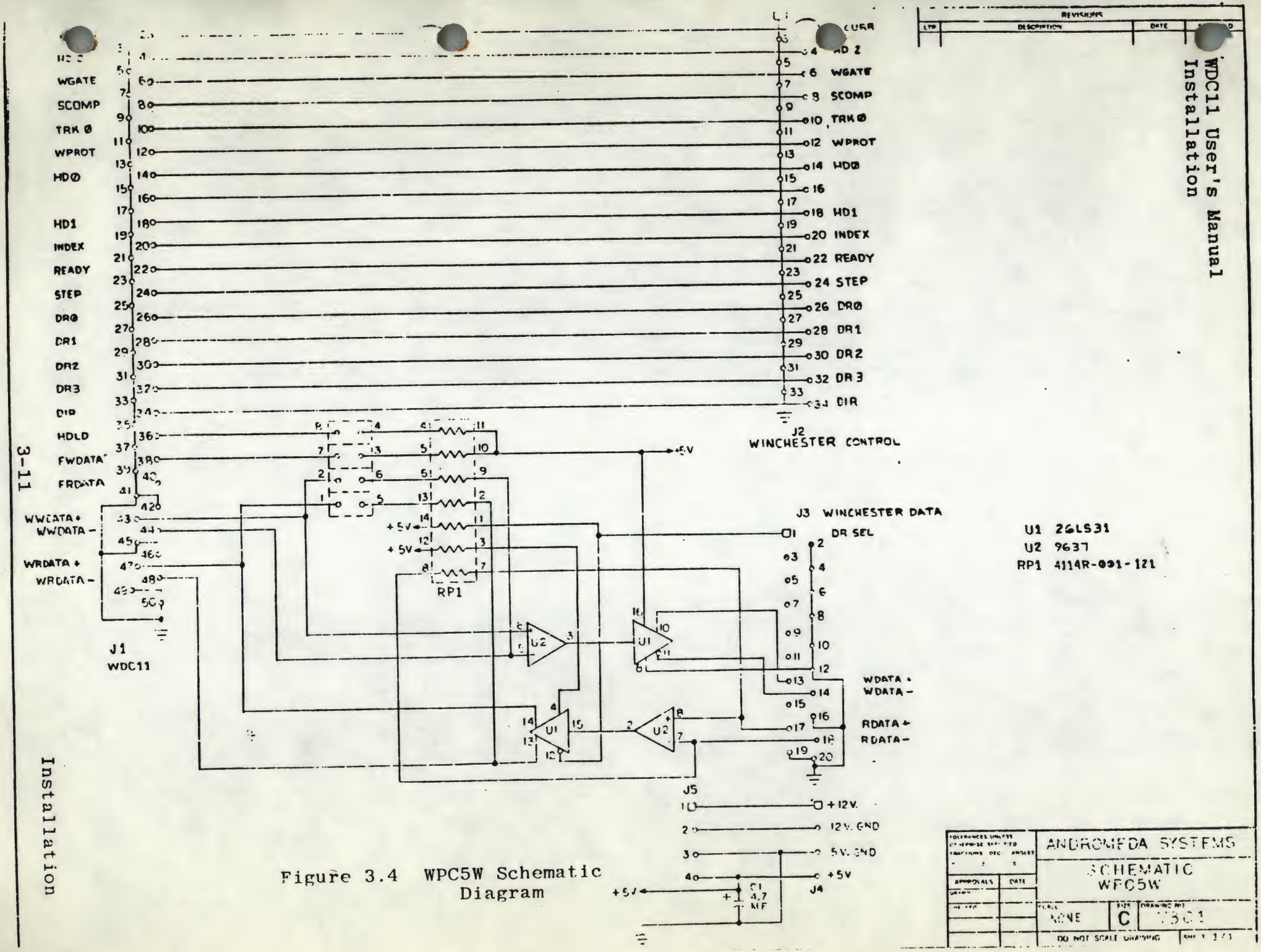


Figure 3.3 WPC5W Installation



U1 26LS31
U2 9637
RP1 4114R-001-121

Figure 3.4 WPC5W Schematic Diagram

ANDROMEDA SYSTEMS
SCHEMATIC
WPC5W
SIZE C
DRAWING NO. 7501
DO NOT SCALE DRAWING

3.4.2.2 WPC8W

The WPC8W personality card serves to connect the 50 line WDC11 disk drive interface cable to 8" Winchester disk drives that have SA1000 type interfaces. A WPC8W is required for each 8" Winchester drive in a system.

There are four jumper pairs on the WPC8W card that must be configured by the user. These jumpers enable termination resistors on control lines when installed.

Jumper Pair	Line Terminated	Configuration
1-8	Winchester Write Data +	Install in last WPC8W only
2-7	Winchester Read Data +	Install in last WPC8W only
3-6	Floppy Head Load L	Leave open in all WPC8W
4-5	Floppy Write Data L	Leave open in all WPC8W

In addition to the above jumpers, the WPC8W has a provision for using a negative power supply voltage other than -5 VDC. WPC8W cards are shipped from the factory set up for -5 VDC, since this is a common voltage used with SA1000 and SA800 disk drives. However, you can install a voltage regulator in position Q2. If you install a 79L05MC, any voltage from -7 VDC to -15 VDC can be used. Be sure that your disk drive is also jumpered for the appropriate negative voltage.

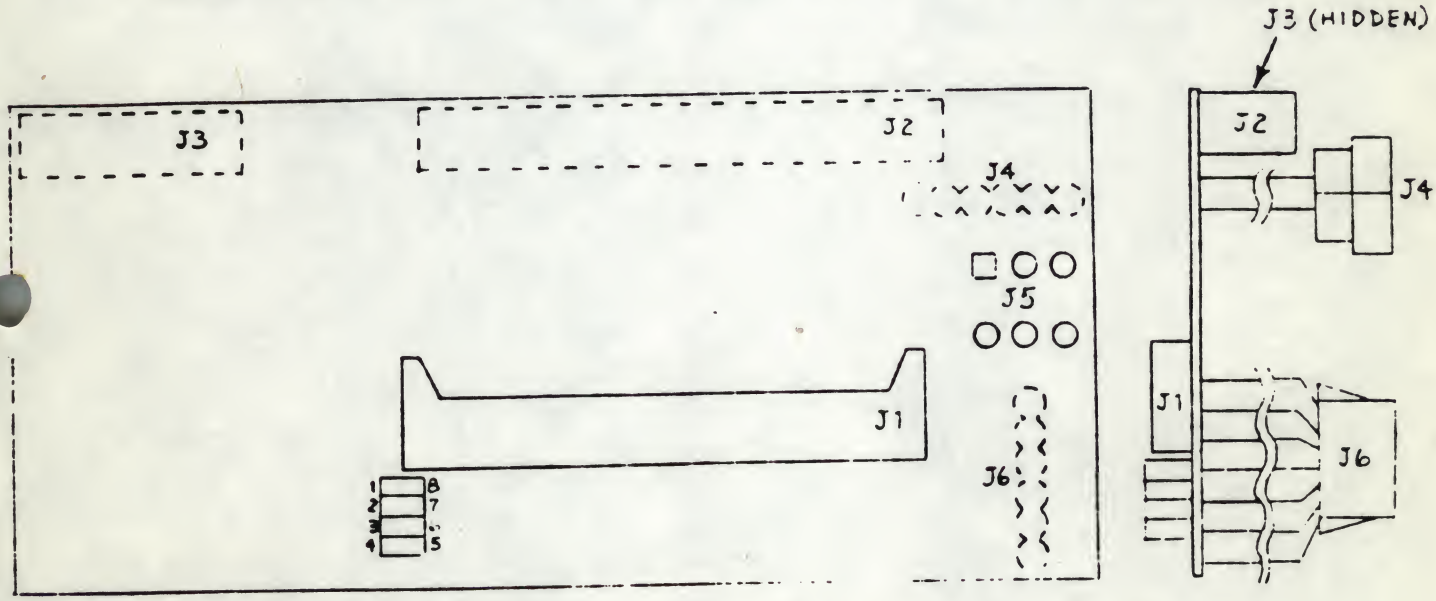


Figure 3.5 WPC8W Physical Board Layout

When the WPC8W has been properly configured for a specific drive, it may be installed on that drive as shown in figure 3.6. The two PC edge connectors of the WPC8W, J2 and J3, plug on to the corresponding connectors of the disk drive. The male power connector of the WPC8W plugs into the female power connector of the disk drive. The male power connector from the system power supply plugs into the female power connector of the WPC8W. Finally, the 50-line disk drive interface cable from the WDC11 plugs into the J1 connector of the WPC8W.

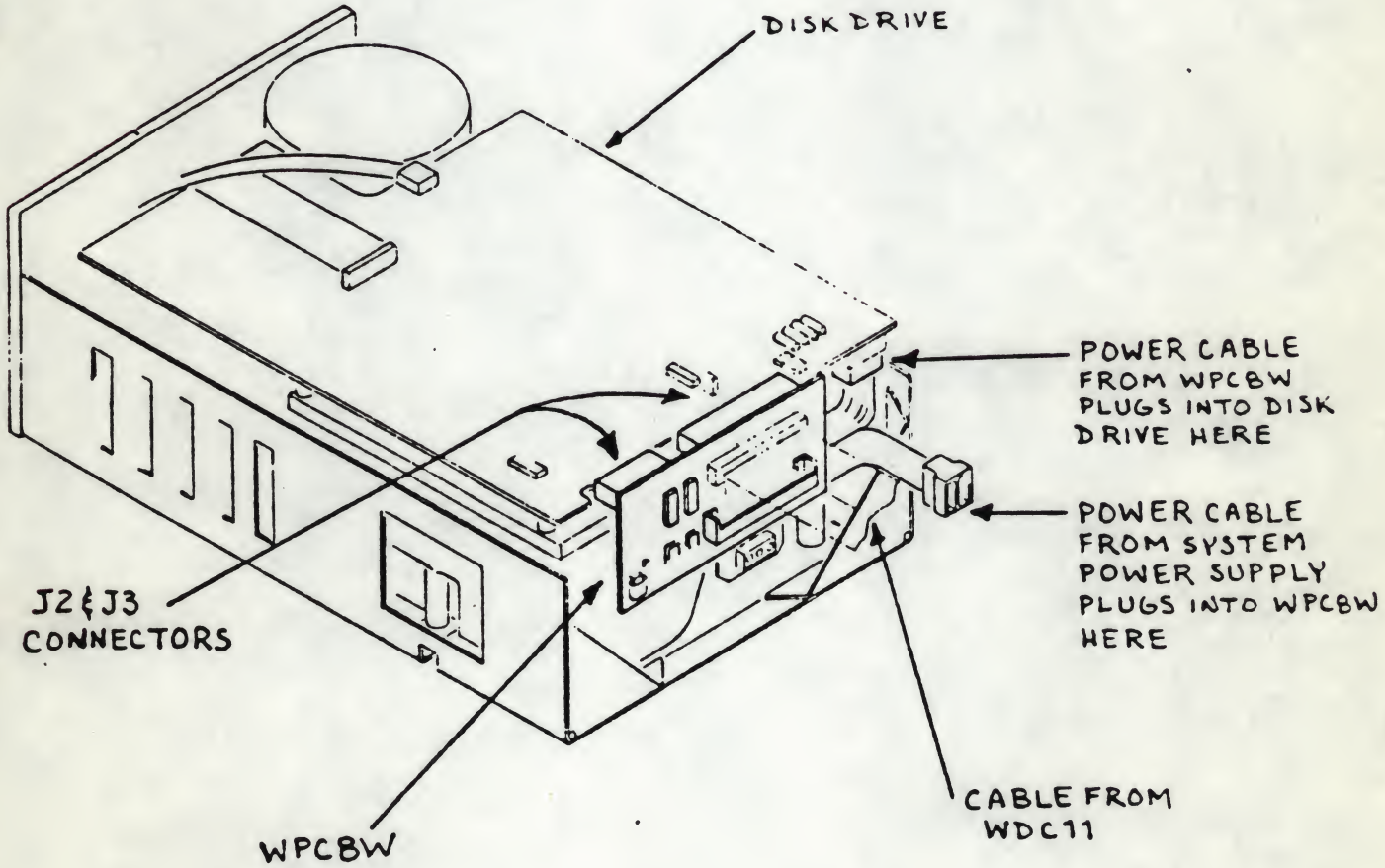


Figure 3.6 WPC8W Installation

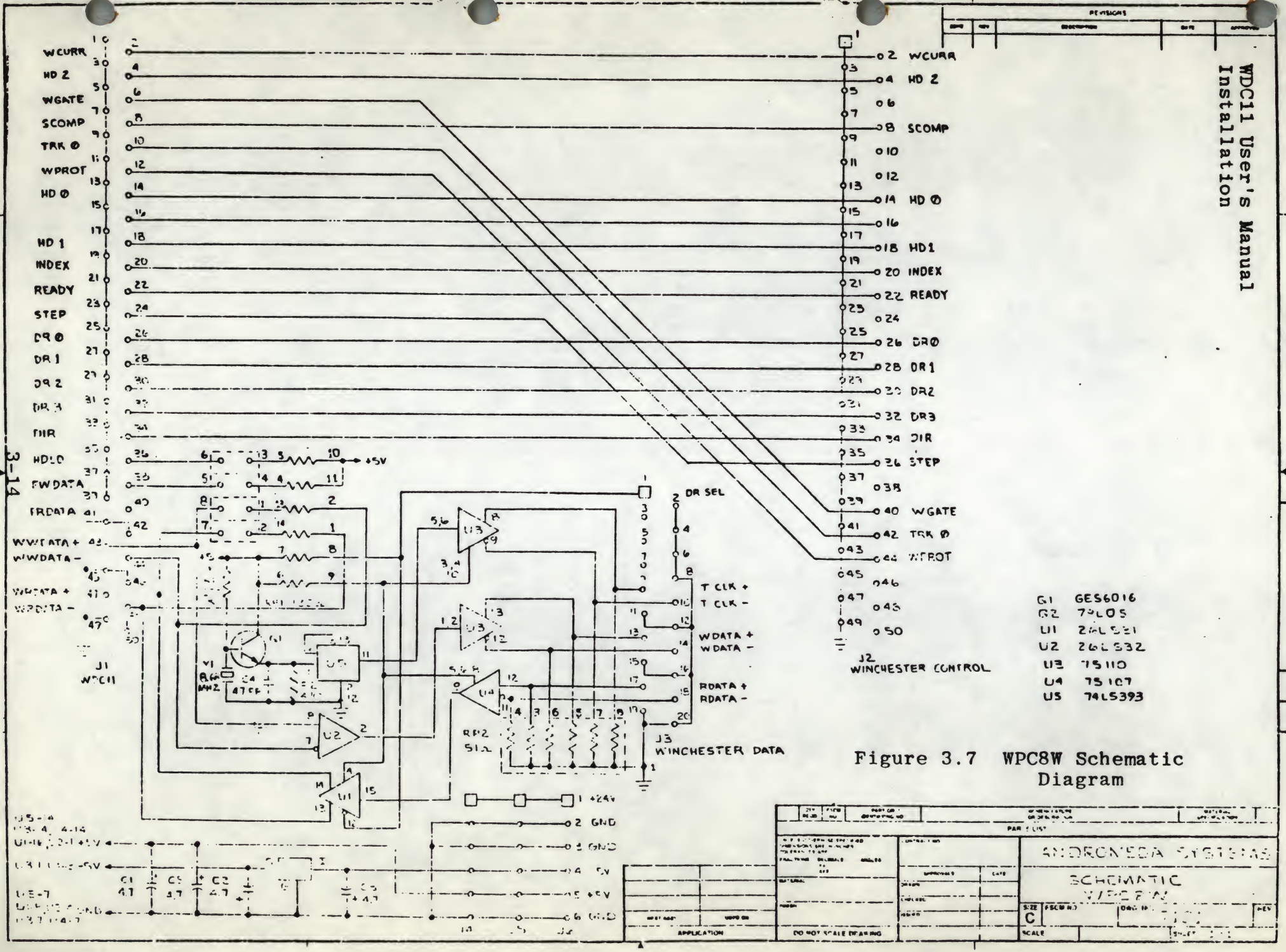


Figure 3.7 WPC8W Schematic Diagram

3.4.2.3 WPC5F

The WPC5F personality card is used to connect the WDC11 50-line disk drive cable to 5.25" floppy disk drives (Tandon Magnetics TM100-4 or equivalent).

The WPC5F contains no user configurable options.

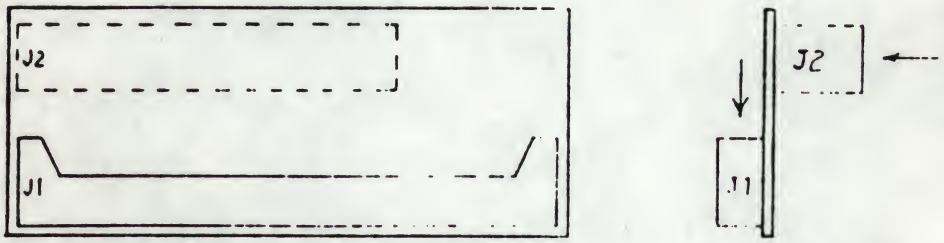


Figure 3.8 WPC5F Physical Board Layout

The WPC5F is installed on a 5.25" floppy disk drive by plugging the J2 connector of the WPC5F on to the J1 connector of the floppy disk drive, as shown in figure 3.9. The 50-line disk drive interface cable from the WDC11 then plugs into the J1 connector of the WPC5F. Observe pin 1 alignment.

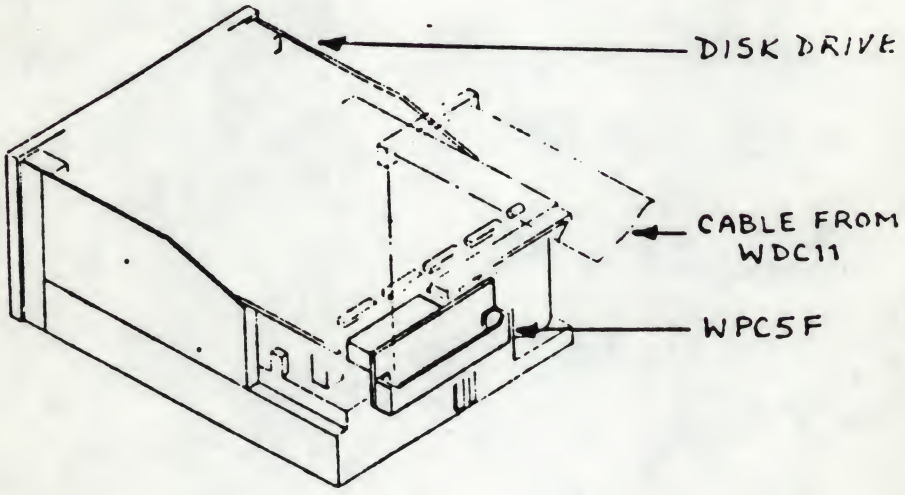


Figure 3.9 WPC5F Installation

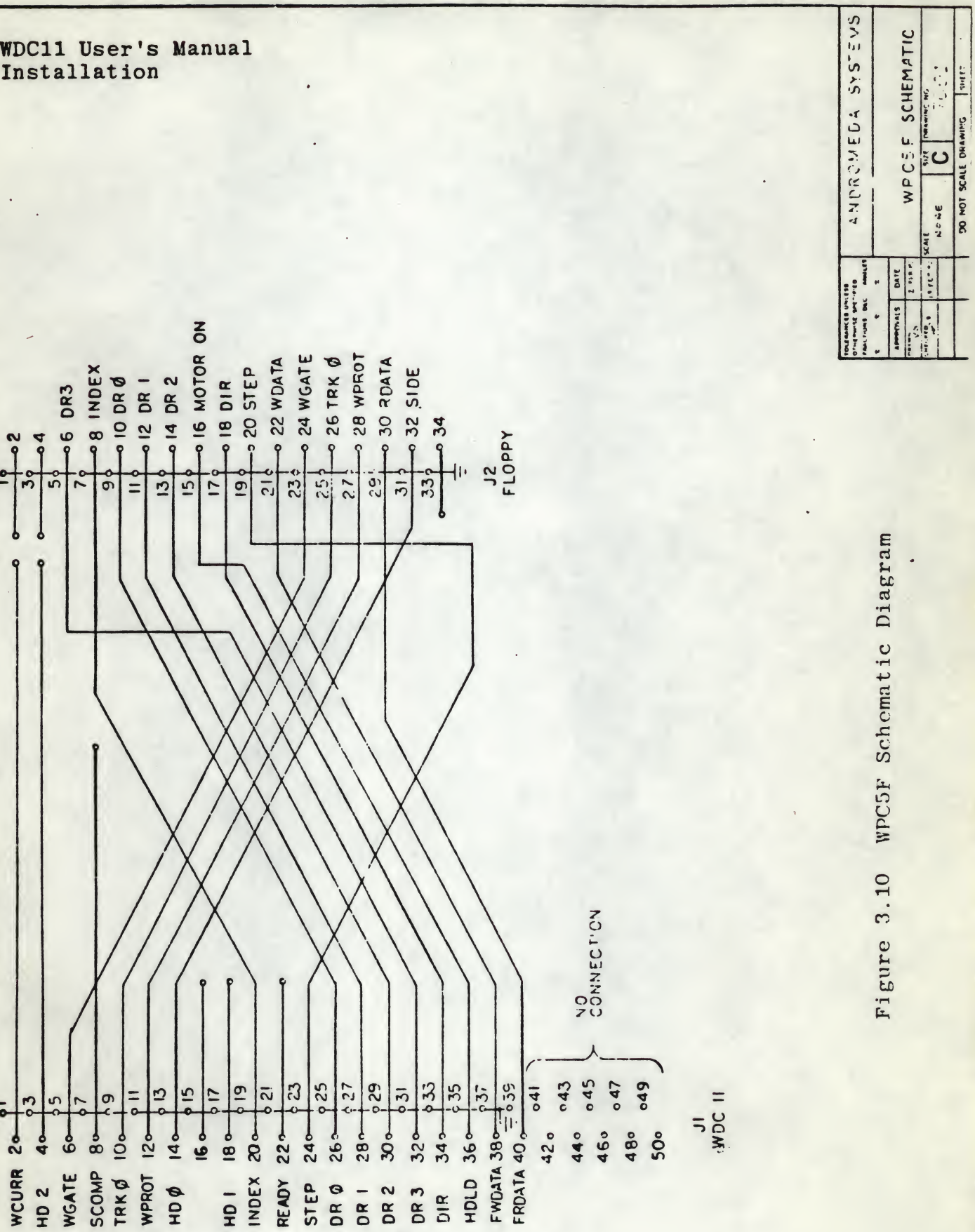


Figure 3.10 WPC5F Schematic Diagram

3.4.2.4 WPC8F

The WPC8F personality card is used to connect the WDC11 50-line disk drive interface cable to 8" floppy disk drives (Shugart Associates SA-800/850 or equivalent).

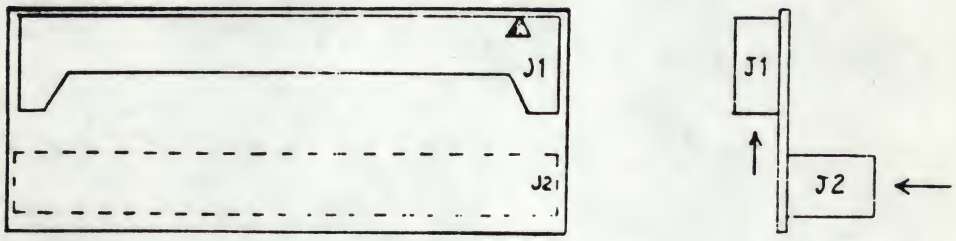


Figure 3.11 WPC8F Physical Board Layout

There are no user configurable options on the WPC8F. It is installed on an 8" floppy disk drive by plugging the J2 connector of the WPC8F on to the J1 connector of the disk drive, as shown in figure 3.12.

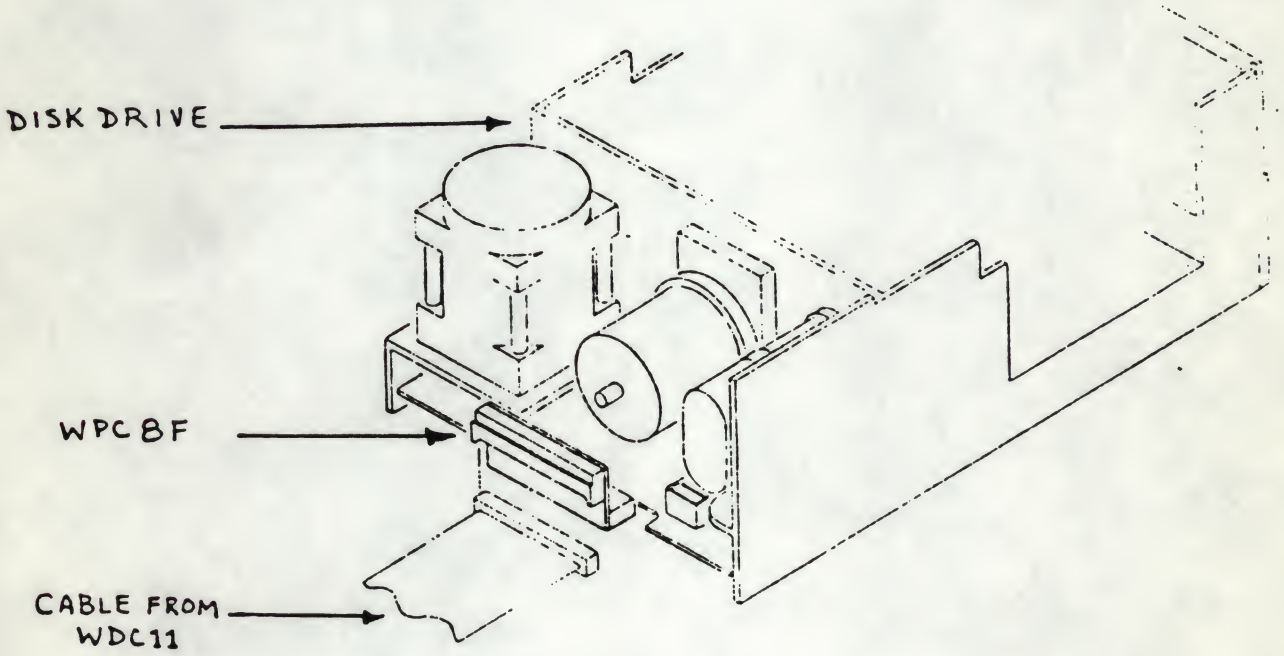


Figure 3.12 WPC8F Installation

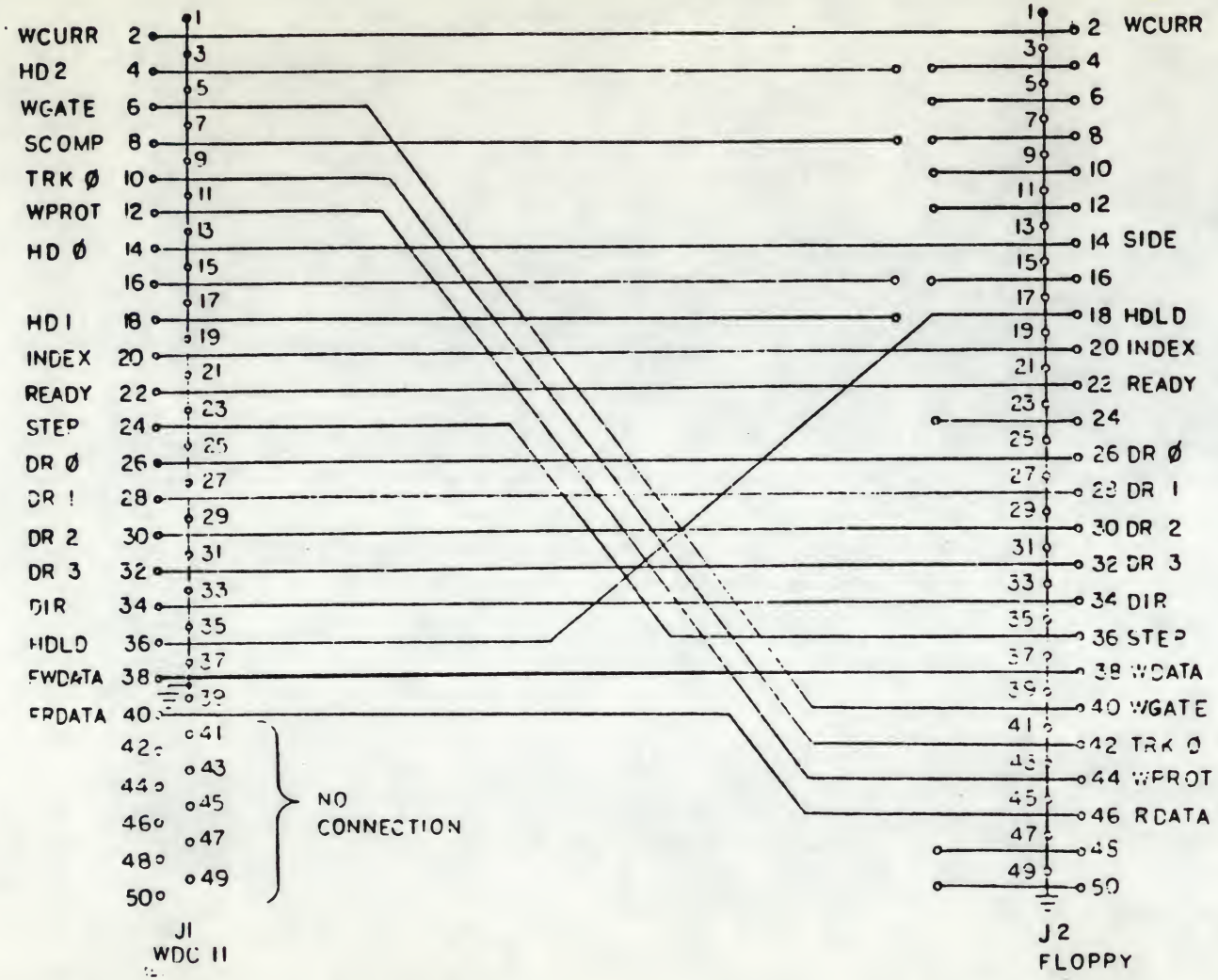


Figure 3.13 WPC8F Schematic Diagram

ANDROMEDA SYSTEMS
WPC8F SCHEMATIC
SCALE NONE | SIZE C | DRAWING NO 7201
DO NOT SCALE DRAWING | SHEET 1/1

3.4.3 Specific Drive Configurations

Each disk drive has a different set of options which must be configured correctly to interface with the WDC11. These options are detailed below. Also, each drive has a package of terminating resistors which must be configured properly for the system to function correctly.

The WDC11 has four drive select lines on its drive interface. These are labeled "DRIVE SELECT 0-3 L" (J1-26 through J1-32). Thus, the WDC11 can control up to four separate physical disk drives. The WBRxxx PROM controls the mapping of logical devices to physical drives. The standard mapping is shown:

Physical Drive Select	Physical Drive
0	First Winchester Drive
1	First Floppy Drive
2	Second Winchester Drive
3	Second Floppy Drive

In a system with a single Winchester drive and two floppy drives, the Winchester drive would be selected when Drive Select 0 L was active. The Winchester drive may actually contain up to 8 logical devices. The first floppy drive must be activated by DRIVE SELECT 1 L and the second floppy drive by DRIVE SELECT 3 L. Each floppy may contain only one logical device (even if it is double headed). The floppy on DRIVE SELECT 1 L would be logical unit 0 (DY0:) and the other floppy drive would be logical unit 1 (DY1:) as far as the computer system was concerned.

It is possible, on special order - at additional cost, to have Andromeda set up a WBRxxx PROM for a different combination of Winchester and floppy drives than that shown above (two Winchesters and two floppies). Any combination of four drives is possible, such as four Winchesters and no floppy or three Winchesters and one floppy. In the case of RL01/2 emulations, all of the logical devices do not need to be the same. Instead of putting three RL02 logical devices in a Q2040 drive, the WBRxxx PROM could be setup for two RL02 and two RL01 logical devices.

Each line that is driven by the WDC11 must be terminated at one (and only one) of the disk drives that are controlled by the WDC11. All except two lines are normally terminated by the last Winchester disk drive (the drive electrically furthest from the WDC11). The three lines that require special consideration are the Floppy Write Data L (J1-38), Floppy Head Load L (J1-36), and the Drive Select x L (J1-26, 28, 30, and 32).

The Floppy Write Data and Head Load lines may be terminated at the floppy disk drive furthest from the WDC11. If your system includes a

Winchester disk drive with a personality card, it is possible to terminate these two lines with the Winchester personality card (WPC5W or WPC8W).

The drive select lines must be terminated by the disk drive that recognizes them. The first Winchester would normally provide the termination for Drive Select 0 L; the first floppy drive would terminate Drive Select 1 L; and so forth. Drive select lines that are not used need not be terminated.

The following disk drives are common units that are supported by the WDC11. The drive option setups required by the WDC11 are shown. It is believed that any drive with the appropriate interface can be controlled by the WDC11, however you may have to determine by trial and error, the correct option setup for a drive that is not listed below. If you have problems, contact Andromeda or your controller dealer. Note that the WBRxxx PROM in the WDC11 must match the drives that you are using.

> Note: Only Winchester drives with a formatted capacity (our format) greater than 5.24 Mbytes can be used as RL01 emulation devices. The Seagate ST506 and Texas Instruments TI506 do not qualify as RL01 emulation devices with the WDC11-C. At least 10.48 Mbytes of formatted capacity are required for an RL02 emulation. At least 2.5 Mbytes of formatted capacity are required for an RK05 emulation.

3.4.3.1 5.25" Winchester Drives

The following 5.25" Winchester disk drive setups have been tested by Andromeda.

Seagate Technology ST506

Jumper	Description	First Drive	Second Drive
8-9	Drive Select 0	In	Out
7-10	Drive Select 1	Out	Out
6-11	Drive Select 2	Out	In
5-12	Drive Select 3	Out	Out
4-13	H	In	In
3-14	(unused)		
2-15	D	In	In
1-16	Radial Enable	Out	Out

Remove terminator pack from all but last drive.

Texas Instruments TI506

Jumper	Description	First Drive	Second Drive
8-9	Drive enable	Out	Out
7-10	Half Skip	In	In
6-11	Recalibrate	In	In
5-12	(unused)		
4-13	Drive Select 0	In	Out
3-14	Drive Select 1	Out	Out
2-15	Drive Select 2	Out	In
1-16	Drive Select 3	Out	Out

Remove terminator pack from all but last drive.

Computer Memories CM5616

Jumper	Description	First Drive	Second Drive
1-2	Drive Select 0	In	Out
3-4	Drive Select 1	Out	Out
5-6	Drive Select 2	Out	In
7-8	Drive Select 3	Out	Out
9-10	Offtrack	Out	Out

Remove terminator pack, RP8, from all but last drive.

Rotating Memory Systems RMS512

Jumper	Description	First Drive	Second Drive
4-5	Drive Select 0	In	Out
3-6	Drive Select 1	Out	Out
2-7	Drive Select 2	Out	In
1-8	Drive Select 3	Out	Out

Remove terminator pack from all but last drive.

Rodime RO104

Jumper	Description	First Drive	Second Drive
1	Drive Select 0	In	Out
2	Drive Select 1	Out	Out
3	Drive Select 2	Out	In
4	Drive Select 3	Out	Out

Remove terminator pack from all but last drive.

3.4.3.2 8" Winchester Drives

The following 8" Winchester disk drive setups have been tested by Andromeda.

Quantum Q2040

Jumper	Description	First Drive	Second Drive
	Drive Select 0	In	Out
	Drive Select 1	Out	Out
	Drive Select 2	Out	In
	Drive Select 3	Out	Out

Remove terminator pack from all but last drive.

Shugart Associates SA1000

Jumper	Description	First Drive	Second Drive
DS1	Drive Select 0	In	Out
DS2	Drive Select 1	Out	Out
DS3	Drive Select 2	Out	In
DS4	Drive Select 3	Out	Out

Remove terminator pack from all but last drive.

3.4.3.3 5.25" Floppy Drives

The following 5.25" floppy disk drive setups have been tested by Andromeda.

Tandon Magnetics TM100-4

	Jumper	Description	First Drive	Second Drive
1E	1-16	HS	Out	Out
	2-15	Drive Select 0	Out	Out
	3-14	Drive Select 1	In	Out
	4-13	Drive Select 2	Out	Out
	5-12	Drive Select 3	Out	In
	6-11	Mux	Out	Out
	7-10	Unused	Out	Out
	8-9	HM	In	In

Termination (in last floppy drive only)

2F 3, 4, 6, 7 Out; all other pins In. Remove terminator pack 2F from all but last floppy drive. The two lines terminated by this package (F WRITE DATA and F HEAD LOAD) may also be

terminated on a WPC5W or WPC8W personality card. In this case, remove the terminator pack from all floppy drives.

3.4.3.4 8" Floppy Drives

The following 8" floppy disk drive setups have been tested by Andromeda.

Shugart SA800/850

Jumper	Description	First Drive	Second Drive
DS1	Drive Select 0	Out	Out
DS2	Drive Select 1	In	Out
DS3	Drive Select 2	Out	Out
DS4	Drive Select 3	Out	In
T2	Terminator, Drive Sel.	In	In
C	Head Load, External	In	In
T1	Terminator, Head Load	see below	
A	Radial Head Load	In	In
B		Out	Out
X		In	In
T6	Terminator, Write Gate	Out	Out
T5	Terminator, Write Data	see below	
T4	Terminator, Step	Out	Out
T3	Terminator, Direction	Out	Out
HL	Stepper Power From HL	Out	Out
DS	Stepper Power From DS	Out	Out
	(Stepper power is on at all times)		
Z	In Use Light From DS	In	In
Y	In Use Light From HL	Out	Out
	(In Use Light is on when drive is selected)		
D	Alternate In Use input	Out	Out
DC	Alternate Disk Change	Out	Out
800	Enable Soft Sector	In	In
801	Enable Hard Sector	Out	Out
DDS	Decode Drive Select	Out	Out
FS	False Separation	In	In
TS	True Separation	Out	Out
RR	Radial Ready	In	In
RI	Radial Index	In	In
R	Ready	In	In
2S	Two Sided Status	Out	Out
I	Index	In	In
S	Sector	In	In
WP	Write Protect	In	In
NP	No Write Protect	Out	Out
DL	Door Lock	Out	Out
S1	Side Select	Out	Out

S2		In	In
S3		Out	Out
IW	Write Current	In	In
RS	Ready Standard	Out	Out
RM	Ready Modified	In	In
IT	Terminator, In Use	Out	Out
HLL	Head Load Latch	Out	Out

Terminators T1 (F HEAD LOAD) and T5 (F WRITE DATA) should only be installed on the last floppy drive. These two lines may also be terminated on a WPC5W or WPC8W personality card. In this case, T1 and T5 should be Out on all drives.

4 Programming

The WDC11 emulates existing DIGITAL disk controllers. Any programming information relative to the RK05 or RL01/2 hard disk controllers, or the RX02 floppy disk controller will apply to the WDC11, except where noted. The WDC11 will execute standard DIGITAL operating system software pertaining to RK05, RL01/2, and RX02 devices, including the RK, DK, DL, and DY handlers, and the FORMAT program for RK05 and RX02.

4.1 RK05 Hard Disk Controller (WDC11-B)

For information on RK05 programming, see the DIGITAL Microcomputer Interfaces Handbook and the DEC RKV11-D User's Manual.

The following differences exist between a DEC RK05 controller and the WDC11:

* RKDS bits 0, 1, 2, 3, 9, 10, and 12 are always read as 0. RKDS bits 4 and 8 are always read as 1.

* RKDS bits 13, 14, and 15 will contain the drive identification after every SEEK or DRIVE RESET operation.

* RKER bit 8 is always read as 0.

* RKER bit 9 is used to indicate that a header field was found and verified but the data field was not found in time.

* RKCS bits 4 and 5 are used as bits 16 and 17 of RKBA. This implements 18 bit addressing.

* RKCS bit 11 (IBA) is not implemented.

* RKCS bit 13 will be set after every SEEK or DRIVE RESET operation. SEEK and DRIVE RESET commands will interrupt only once, when the operation is complete. Overlapped seeks are not supported.

* The SEEK and DRIVE RESET functions perform no movement of the drive heads. SEEK and DRIVE RESET operations are performed automatically during READ and WRITE operations.

* The READ FORMAT function operates identically to the READ function.

* The WRITE CHECK function performs no operation. A WRITE CHECK will always appear successful.

* The READ CHECK function performs no operation. A READ CHECK will always appear successful.

* The WRITE LOCK function performs no operation.

* The unused register (RKDS+14) is used as a bus extension register. Bits 0-5 correspond to address bits 16-21 during DMA transfers. Writing to bits 0 and 1 of this register will affect the state of RKCS bits 4 and 5, and vice-versa. This allows you to implement 22-bit addressing with your own software.

* The WDC11 will not assert BBS7 when performing DMA to an address in the I/O page.

* The RKDB is used to pass formatting data to the WDC11 during WRITE FORMAT operations. See section 6 on formatting for details. Other than this, the RKDB is unused.

4.2 RL01/2 Hard Disk Controller (WDC11-C)

For information on RL01/2 programming, see the DIGITAL Microcomputer Interfaces Handbook and the DEC RLV12 Disk Controller User's Guide.

The following differences exist between a DEC RL01/2 controller and the WDC11:

* The DLT error indicates that the correct header was found and verified but the data mark was not not found.

* The NO-OP maintenance function is not implemented.

* The WRITE CHECK function performs no operation. A WRITE CHECK will always appear successful.

* The SEEK function is not implemented. Since virtual RL01/2 cylinders do not have a one-to-one correspondence with the physical cylinders on a Winchester disk drive, performing a SEEK without the virtual head and sector information could position the heads on the wrong cylinder. SEEK operations are performed automatically during READ and WRITE operations, when this information is available.

* The READ HEADER operation returns three words of zeros. Since the READ HEADER is typically used to determine the current cylinder in preparation for a SEEK, this should have no system impact. The software will think the drive is at cylinder 0, and issue a SEEK to the desired cylinder. This seek will be ignored. When a READ or WRITE command is issued, the actual SEEK will take place. However, the WDC11 does update its internal physical cylinder register when a READ HEADER is performed. This facility is used to recover from head positioning errors.

* The WRITE command is also used to FORMAT. See section 6 on formatting for details.

* The parity error abort function of the RLV12 is not implemented on the standard WDC11-C, contact Andromeda if you require this function.

* The WDC11 will not assert BBS7 when performing DMA to an address in the I/O page.

4.2 RX02 Floppy Disk Controller

For information on RX02 programming, see the DIGITAL Microcomputer Interfaces Handbook and the DEC RX02 Floppy Disk System User's Manual.

There are no significant differences between the DEC RXV21 controller and the floppy section of the WDC11.

5 Bootstrap ROM

The WDC11 contains a bootstrap ROM (WBRxxx) which normally responds to Q-Bus addresses 773000 thru 773776. The WDC11 bootstrap ROM (U87) contains three elements:

* Bootstrap code for RK05 or RL01/2, and RX02
* Interrupt vectors for RK05 or RL01/2, and RX02
* Drive configuration information

The bootstrap code extends from 773000 thru 773676. The LSI-11 processor can be jumpered to always execute this code upon power up or system reset. When the code is executed, it enters a loop which waits for one of three events to occur:

RK0: (DK0:) or DL0: becomes ready, or
DY0: becomes ready, or
any key is pressed on the console terminal

If RK0: (DK0:), DL0:, or DY0: becomes ready, the WDC11 will automatically attempt to bootstrap from that unit. If a key is pressed on the console terminal, the program will prompt the operator with:

Device?

The operator then enters a two letter device name, optional unit number, and optional colon (:). When RETURN is pressed, the program scans the line for correct syntax. If the syntax is correct, the program will wait for the specified unit to become ready, and attemp to bootstrap from that unit. If the syntax is incorrect, the device prompt will be repeated.

The first key pressed (the one that initiated the prompt) is used as the first character of the line. Lower case letters are permitted, and function just like upper case letters. Also, syntax is scanned from the end of the line to the beginning. If you make a mistake, just start over.

Examples of valid input are:

```
RK      DK:     DL0     DY1:
dy      dk:     rk7     d13:
this is a mistakeDY1:
```

Two more operator convenience features are incorporated. When the code is first executed, there is a short delay (less than 1 second) before

the loop begins. This gives an operator time to press a key in case an undesired disk is already ready. Also, if the code is executed at 773002 (enter 773002G from console microcode ODT), it will not automatically bootstrap DL0: or DY0: but will immediately prompt the operator for the device.

The rest of the bootstrap ROM (773700 thru 773776) is used for system configuration information. It contains, among other things, the interrupt vectors for the RK05 or RL01/2 and the RX02, and the drive configuration information. This chip must remain installed even if the bootstrap ROM is disabled by removing jumper S1. To change these parameters, a different ROM must be installed. The new ROM must contain all of the information from 773700 thru 773776 for the WDC11 to function correctly. If you are considering creating a new drive configuration PROM to use a configuration not supported by Andromeda, see Appendix A for a map of the drive configuration words in the WBRxxx PROM.

> Note: The bootstrap ROM function of the WDC11 is unusual in its actual operation. Because of the multi-function nature of the WDC11, the LSI-11 code contained in the bootstrap ROM addresses is not actually executed from these addresses. Rather, the first thing that the WDC11 Bootstrap code does is copy itself into system RAM memory starting at location 1000. The code then performs a jump into the copy and executes the code there. This two-step process is required because the bootstrap ROM of the WDC11 is emulated in a manner similar to the disk controllers of the WDC11. Since the WDC11 can support only one emulation at a time, the actual execution of the bootstrap code is transfered outside of the WDC11. This operation is totally transparent to the user. The only requirement is that there be functional RAM memory in the system from location 1000 to 1676.

6 Formatting

This section discusses the unique formatting functions provided by the WDC11 controllers.

6.1 RK05 Formatting (WDC11-B)

The RK05 WRITE FORMAT command has a few additions and modifications to support formatting of Winchester disk drives. However, standard formatting software (such as the RT-11 FORMAT program) will execute corectly without modification.

The first discrepancy between formatting a real RK05 disk and a Winchester disk emulating an RK05 is that the real RK05 is able to format individual sectors while a Winchester disk drive must format an entire track at once. This is complicated by the fact that a real RK05 contains 12 sectors per track while a Winchester disk contains 16. Therefore, the WDC11 will only perform a format operation when the logical block number is divisible by 16. Referring to the fields in the RKDA,

logical block number=sector+(head*12)+(cylinder*24).

When the logical block number is not divisible by 16, the WRITE FORMAT function operates identically to the WRITE function. When standard format software is executed, this scheme results in one format operation (16 sectors) followed by 15 normal write operations. Formatting software which attempts to format individual sectors will not work correctly with the WDC11-B.

Two variables need to be considered during formatting. They are the sector to sector interleave and the track to track skew.

The sector to sector interleave is specified by the low byte of the RKDB. However, the value passed in this byte is not the actual interleave, but the increment which must be added to each sector (modulo 16) to produce the number of the next sector. Since there are 16 sectors per physical track, this increment must be in the range 0..15. Even values are illegal, and if an even value is specified, that value+1 will be used.

The normal sector to sector interleave is 3. This requires an increment of 11. Since standard format software does not pass information in this byte, a default case is implemented. When this byte is 0 (or 1), the WDC11-B will default to an increment of 11. On systems with a lot of DMA overhead, an interleave of 5 may be required to maximize system performance. The increment for a 5 sector interleave is 13. The increments for each interleave value are shown below (all values are decimal):

INT	INC	INT	INC
3	11	11	3
5	13	13	5
7	7	15	15
9	9		

The track to track skew is specified in the high byte of the RKDB. This byte will contain the number of the first sector on the track currently being formatted. The normal track to track skew is 0 (every track begins with sector 0).

A routine, written in PASCAL, which will format a virtual RK05 unit with a sector to sector interleave of 3 and a track to track skew of 0 is shown below:

```
var
   unit, lsn, word: integer;

begin
rkda:=unit*8192;              (* select unit *)
rkcs:=15B;                    (* cause a drive restore *)
while rkcs and 128=0 do;
word:=0;                      (* data buffer for WRITE FORMAT *)
lsn:=0;
while lsn<4896 do
   begin
   rkdb:=0;                   (* 1st sector=0, increment:=11 *)
   rkda:=unit*8192+lsn div 12*16+lsn mod 12;
   rkba:=@word;               (* address of word *)
   rkwc:=-1;
   rkcs:=2003B;
   while rkcs and 128=0 do;
   if rkcs and 32768<>0 then
      writeln('?WRKFT-Formatting error');
   lsn:=lsn+16
   end
end
```

6.2 RL01/2 Formatting (WDC11-C)

RL01 and RL02 disk packs come from DIGITAL preformatted, and it is impossible to reformat these disks in the field using a DEC RL01/2 controller. However, Winchester disk drives do not come preformatted, and must be formatted by the WDC11 before use. In addition, DIGITAL maintains a bad block table on the last track of each RL01/2 disk pack, which must be present on each virtual RL01/2 unit for DEC software to function correctly.

A special case of the WRITE command is used to accomplish formatting. A WRITE command will FORMAT under the following conditions:

All bus address bits (including extended address bits) are set to 1.

A valid virtual disk address is given.

The word count is in the range 0..31.

Two variables need to be considered during formatting. They are the sector to sector interleave and the track to track skew.

The sector to sector interleave is specified by the word count. However, the value passed in the word count is not the actual interleave, but the increment which must be added to each sector (modulo 32) to produce the number of the next sector. Since there are 32 sectors per physical track, this increment must be in the range 0..31. Even values are illegal, and if an even value is specified, that value+1 will be used.

The normal sector to sector interleave is 3. This requires an increment of 11. On systems with a lot of DMA overhead, an interleave of 5 may be required to maximize system performance. The increment for a 5 sector interleave is 13. The increments for each interleave value are shown below (all values are decimal):

	INT	INC	INT	INC
	1	1	17	17
X	3	11	19	27
	5	13	21	29
	7	23	23	7
	9	25	25	9
	11	3	27	19
	13	5	29	21
	15	15	31	31

The track to track skew is specified in a slightly more complicated manner. During FORMAT (as during READ and WRITE) the virtual disk

address is converted to a physical disk address. A virtual track contains 40 sectors while a physical track contains 32. Since we're formatting physical tracks, we need to initiate a FORMAT operation every 32 sectors. If we think in terms of a logical sector number, which will be converted by the software to a virtual disk address, this lsn must be incremented by 32. This lsn modulo 32 is the number of the first sector on the physical track. The normal track to track skew is 0 (every track begins with sector 0).

A routine, written in PASCAL, which will format a virtual RL01/2 unit with a sector to sector interleave of 3 and a track to track skew of 0 is shown below:

```
var
   unit, lsn: integer;
   rl02: boolean;

begin
rlcs:=unit*256+10B;                (* cause a drive restore *)
while rlcs and 128=0 do;
rlcs:=unit*256+4;                  (* RL01 or RL02? *)
while rlcs and 128=0 do;
rl02:=rlmp and 128<>0;
lsn:=0;
while (lsn<20480) or rl02 and (lsn<40960) do
   begin
   rlmp:=11;                                (* interleave=3 *)
   rlda:=lsn div 40*64+lsn mod 40;          (* skew=0 *)
   rlba:=-1;
   rlcs:=unit*256+72B;
   while rlcs and 128=0 do;
   if rlcs and 32768<>0 then
      writeln('?WDLFT-Formatting error');
   lsn:=lsn+32
   end
end
```

The last track on RL01/2 disk packs is used for a bad block table. A valid table must be present for DEC software to function correctly. The following outlines a valid bad block table.

> Sectors 0, 4, 8, 12, 16, 20, 24, 28, 32, 36: Four words of 0 followed by 124 words of -1
>
> All other sectors: 128 words of -1

This initializes the bad block table to contain no bad blocks. Entries may be made into the bad block table by software particular to your operating system. For example, under RT-11 the command to update the bad block table for DL0: is: INITIALIZE/REPLACE DL0:.

6.3 RX02 Formatting

The standard formatting software supplied by DEC is used to format RX02 and RX01 media. The most significant difference between formatting on DEC hardware and using the WDC11, is that the WDC11 formats both header and data fields (DEC hardware formats only data fields, requiring the header fields to be intact). The WDC11 can successfully reformat a completely demagnetized diskette, an operation not possible with DEC hardware.

Appendix A

Address & Bootstrap/Configuration PROM Formats

This appendix describes the formats of the Address and Bootstrap / Configuration PROMs. This information is provided for those users who may require a configuration not supported by a current Andromeda standard PROM and who do not wish to wait for Andromeda to create a special PROM. Sufficient detail is provided so that you may create your own PROMs for the WDC11.

A.1 Address PROM

The WDC11 Address recognition PROM determines which Q-Bus addresses the four pseudo-devices of the WDC11 will respond to. Even if a range of addresses is defined in the WADxxx PROM, the corresponding jumper, S0-S3, must also be installed in order for the WDC11 to respond.

The normal WADxxx PROM is implemented with a TI 24SA41 integrated circuit. This is a 1024 x 4 PROM. Each of the four outputs corresponds to one of the four pseudo-devices of the WDC11. The outputs are active low, i.e., when an address to be recognized is presented to the WDC11, one (and only one) of the four outputs of the WADxxx PROM will go low. The inputs and outputs of the WADxxx PROM correspond to Q-Bus addresses and WDC11 pseudo-devices as shown in the following table:

Q-Bus Line	PROM Address Input Pin Number	WDC11 Pseudo Device	PROM Output Pin Number
BDAL2	5	S0	14
BDAL3	6	(Maintenance Registers)	
BDAL4	7		
BDAL5	4	S1	13
BDAL6	3	(Bootstrap ROM)	
BDAL7	2		
BDAL8	1	S2	12
BDAL9	17	(Floppy Disk Controller)	
BDAL10	16		
BDAL11	15	S3	11
BDAL12	8	(Winchester Disk Controller)	

Since BDAL2 controls the least significant bit of the PROM, the minimum number of contiguous addresses that the WADxx PROM will respond to is four. Each Q-Bus address corresponds to a single 8-bit byte, so four bytes, or two words, is the smallest recognition increment. This is appropriate for a peripheral controller since a normal peripheral device will require one word for a Command/Status Register and one word for a Data Register.

In addition to the addresses input to the PROM, the WDC11 also requires that Q-Bus line BBS7 be asserted before it will respond. Thus, the WDC11 can respond only to addresses that lie within the 4KW I/O page.

To program a WADxxx PROM, you must put a 0 in the bit that corresponds to the pseudo-device at each address that the pseudo-device should recognize (generate Q-Bus BRPLY). If a pseudo-device address range is only two Q-Bus words, only one bit in the PROM need be set to zero. For a four word device, two consecutive bits in the PROM must be zeroed. For 256 continuous addresses (such as the boot ROM), 128 continuous bits in the PROM must be cleared. All other bits in the PROM must be set to ones (or they will cause their WDC11 pseudo-devices to recognize and respond to addresses that they should not).

The following table of Q-Bus/WADxxx PROM address correspondence will enable you to create your own WADxxx PROM, if a standard Andromeda PROM is unavailable for your application.

Q-Bus Address (octal)	WADxxx PROM Chip Address (hex)	
000000-157776	Unavailable	
160000-160002	7FF	(For Q-Bus Address Range 160000-167776, you must use a 24SA81 chip instead of a 24SA41.)
164000-164002	5FF	
170000-170002	3FF	
170500-170506	2AF-3AE	(WDC11 Maintenance Registers)
173000-173776	27F-200	(Bootstrap ROM addresses)
174000-174002	1FF	
174400-174416	16F-16C	(RL01/2 Controller Addresses)
177170-177172	061	(RX02 Controller Addresses)
177400-177404	03F-03C	(RK05 Controller Addresses)
177774-177776	000	

The WDC11 microcode makes certain assumptions as to where in the I/O page certain types of devices will exist. In other words, areas of the I/O page are reserved for specific types of devices. For example, it is not possible to put a floppy disk controller at address 177400; that area is reserved for hard disk controllers. A map of the reserved areas appears below:

Address	Reserved for
760000-767776	(same as 770000-777776)
770000-770776	Maintenance Registers (do not use)
771000-771776	Bootstrap ROM
772000-772776	Maintenance Registers (do not use)
773000-773776	Bootstrap ROM (standard address)
774000-774376	Floppy Disk
774400-774776	Winchester Disk (standard address for RL01/2)
775000-775376	Floppy Disk
775400-775776	Winchester Disk
776000-776376	Floppy Disk
776400-776776	Winchester Disk
777000-777376	Floppy Disk (standard address for RX02)
777400-777776	Winchester Disk (standard address for RK05)

A.2 Bootstrap/Configuration PROM

The WDC11 Bootstrap/Configuration PROM contains bootstrap code, interrupt vectors, and drive configuration information. The WBRxxx PROM is implemented with a TI 28S42 integrated circuit. This is a 512 x 8 PROM. Specific areas of this PROM are reserved for each function. A map of the WBRxxx PROMs appears below. This will enable to create your own WBRxxx PROM if a standard Andromeda PROM is unavailable for your application. Q-bus addresses are relative to the base of the bootstrap ROM (normally 773000).

Q-bus Address (octal)	PROM Address (hex)	Description
000-677	000-1BF	Bootstrap code. If you write your own bootstrap, it must fit within this area. Also, if your code accesses any of the devices emulated by the WDC11, it must copy itself to RAM, and execute from RAM. The WDC11 cannot emulate a bootstrap ROM and a disk controller concurrently.
700-733	1C0-1DB	Reserved. These locations must not be altered.
734,5	1DC,D	Hard disk interrupt vector (must be even).

736,7	1DE,F	Floppy disk interrupt vector (must be even).
740-747	1E0-1E7	Reserved. These locations must not be altered.

The following section pertains to RK05 emulations (WBRBxx).

750	1E8	RK0 unit map byte (note 1).
751	1E9	RK1 unit map byte.
752	1EA	RK2 unit map byte.
753	1EB	RK3 unit map byte.
754	1EC	RK4 unit map byte.
755	1ED	RK5 unit map byte.
756	1EE	RK6 unit map byte.
757	1EF	RK7 unit map byte.
760,1	1F0,1	Number of physical cylinders per physical platter -1. This value (before subtracting 1) comes from the drive specifications.
762,3	1F2,3	Physical cylinder to reduce write current -1. This value (before subtracting 1) comes from the drive specifications. A value of -1 indicates never to activate the reduce write current control line.
764	1F4	Number of physical cylinders per virtual unit -1. This value (before subtracting 1) must be between 153 and 192 (inclusive, decimal), and must be divisible by 3 (note 2).
765	1F5	Step rate (in 100 usec intervals) -1. This value (before subtracting 1) comes from the drive specifications.
766,7	1F6,7	Unused.

The following section pertains to RL01/2 emulations (WBRCxx).

750	1E8	DL0 (cylinders 0-255) unit map byte (note 1).
751	1E9	DL0 (cylinders 256-511) unit map byte.
752	1EA	DL1 (cylinders 0-255) unit map byte.
753	1EB	DL1 (cylinders 256-511) unit map byte.
754	1EC	DL2 (cylinders 0-255) unit map byte.
755	1ED	DL2 (cylinders 256-511) unit map byte.
756	1EE	DL3 (cylinders 0-255) unit map byte.
757	1EF	DL3 (cylinders 256-511) unit map byte.
760,1	1F0,1	Number of physical cylinders per physical platter -1. This value (before subtracting 1) comes from the drive specifications.

762,3	1F2,3	Physical cylinder to reduce write current -1. This value (before subtracting 1) comes from the drive specifications. A value of -1 indicates never to activate the reduce write current control line.
764,5	1F4,5	Number of physical cylinders per virtual unit (1's compliment). This value (before complimenting) must be greater than or equal to 320 (decimal) and must be divisible by 5 (note 2).
766	1F6	Step rate (in 100 usec intervals) -1. This value (before subtracting 1) comes from the drive specifications.
767	1F7	Unused.

The following section pertains to RX02 emulation (all PROMS).

770	1F8	DY0 unit map byte (note 1).
771	1F9	DY1 unit map byte.
772	1FA	Floppy type byte. 0=8" single headed. 1=8" double headed. 2=5.25" double headed, 80 tracks.
773	1FB	Unused.
774	1FC	Step rate (in 100 usec intervals) -1. This value (before subtracting 1) comes from the drive specifications.
775	1FD	Settling time (in 100 usec intervals) -1. This value (before subtracting 1) comes from the drive specifications.
776,7	1FE,F	Head load delay (in 100 usec intervals) -1. This value (before subtracting 1) comes from the drive specifications. For 5.25" floppies, this is the motor on delay.

Note 1 Unit map bytes

Each virtual RK, DL, or DY unit may reside on one of four physical drives. Also, one physical Winchester drive may contain more than one virtual RK or DL unit. This virtual unit to physical device mapping is specified in the unit map bytes. Each unit map byte specifies whether or not that virtual unit exists, on which physical drive it exists, and, for RK or DL units, where on that drive it exists.

Each virtual RK or DY unit has a unit map byte. Virtual DL units have two map bytes, one for virtual cylinders 0-255, and one for virtual cylinders 256-511. Therefore, a virtual DL unit which is emulating an RL02 may reside on two physical drives. Also, a virtual DL unit may emulate an RL01 by having cylinders 256-511 specified as non-existent.

The format for a unit map byte is:

Bits 7..6	Physical drive number.
Bit 5	1 if non-existent unit (all other bits are ignored).
Bits 4..3	Unused.
Bits 2..0	Virtual unit within this physical drive (unused for DY).

For example, an ST506 drive may contain 2 RK units. If we limit ourselves to physical drives 0 and 2 (reserving drives 1 and 3 for floppies), then we can only emulate RK0-4. In this case, RK4-7 are non-existent, and the RK unit map bytes look like this (octal):

0, 1, 200, 201, -1, -1, -1, -1

A CMI5616 drive may contain 5 RK units. If we wish to put rk0-1 on drive 0 and rk5-7 on drive 2, the RK unit map bytes would look like this (octal):

0, 1, 2, 3, 4, 200, 201, 202

A CMI5616 drive may also contain one RL02 unit. To put DL0 on drive 0 and DL1 on drive 2, the DL unit map bytes are (octal):

0, 1, 200, 201, -1, -1, -1, -1

To make each CMI5616 drive look like two RL01's, the unit map bytes are (octal):

0, -1, 1, -1, 200, -1, 201, -1

Each floppy drive can contain 1 DY unit. To map DY0 to physical drive 1 and DY1 to physical drive 3, the DY unit map bytes must look like this (octal):

100, 300

Note 2 Physical and virtual devices

The number of physical cylinders per platter multiplied by the number of platters must be greater than or equal to the number of physical cylinders per virtual unit multiplied by the number of virtual units per physical drive (from the unit map bytes). In other words, you can't fit more data on a disk than you have space for.

Virtual RK and DL units are packed onto a Winchester drive on a platter by platter basis. By changing the number of physical cylinders per platter and the number of physical cylinders per virtual unit, we can control this packing process.

On an ST506 drive emulating RK's, the packing process is not alterable. Each platter holds 153 cylinders, and there are 153 cylinders per virtual unit. On a CMI5616 drive emulating RK's, each platter holds 256 cylinders. Since there are three platters, we have 768 cylinders available. Each RK unit still requires 153 cylinders, so to pack 5 RK's on one drive, we require 765 cylinders. By telling the WDC11 that the CMI5616 drive contains only 255 cylinders instead of 256, we can cause one unused cylinder to be at the center of each of the three platters, instead of all three at the center of the last platter.

By changing the RK unit map bytes, we could also cause the CMI5616 drive (using all 256 cylinders) to contain four RK units, each using 192 physical cylinders. In this case, each virtual RK unit would contain 6144 sectors (256 virtual tracks) instead of the normal 4896 sectors (204 virtual tracks). Special software would be required to use this additional space.

Each RL01 unit requires 320 cylinders. If we pack two RL01's on a CMI5616 drive, we have 128 cylinders left over. We can cause these spare cylinders to be in the center of each platter by telling the WDC11 that a CMI5616 drive has only 213 cylinders instead of 256 (in this case there would be 43 spare cylinders on the first two platters and 42 on the third). We can cause the spare cylinders to be at the end of each virtual unit by telling the WDC11 that there are 385 cylinders per virtual unit (in this case, there would be 65 cylinders following DL0 and 63 cylinders following DL1). Or we could combine the two and tell the WDC11 that a CMI drive contains 240 cylinders and that a DL unit contains 360 cylinders (in this case, there are 40 cylinders following each virtual unit and 16 cylinders at the center of each platter). This is the packing method employed by Andromeda when we put DL's on a CMI5616 drive.

Note that, unlike the RK emulation, there is no way to access spare cylinders within a virtual DL unit. This is because there is no way to specify a cylinder number greater than 511 in the RL01/2 device address register. At Andromeda, we leave the spare cylinders there for future expansion of the WDC11 microcode.

Appendix B

WDC11 Configuration Sheet

Part # WDC11-____ S/N _____

S.O.#_____ Customer_____ Date Shipped_____

Jumpers:		I/R	Function (I=installed, R=removed)
Device Select:	S0	_____	Maintenance Registers
	S1	_____	Bootstrap ROM
	S2	_____	Floppy Disk Controller
	S3	_____	Winchester Disk Controller
Interrupt Level:	I5	_____	Interrupt level 5
	I6	_____	Interrupt level 6 or 7
	I7	_____	Interrupt level 7
Winchester:	8WR, 8WW	_____	8" Winchester Controller
	5WW	_____	5.25" Winchester Controller
Floppy:	8FR, 8FW	_____	8" Floppy Controller
	5FR, 5FW	_____	5.25" Floppy Controller

PROMS:	Function	Installed type
	Address Recognition	WAD_____
	Bootstrap ROM	W _____
	Microcode	WDC_____